Supplement of

Modulation of daily PM$_{2.5}$ concentrations over China in winter by large-scale circulation and climate change

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Supporting information

Figure S1: UKESM1-simulated winter mean daily 500 hPa geopotential height (Z500; m, shading) and 850 hPa wind (arrows) during DJF 1999–2018.
Figure S2: Anomalies (heavily polluted days minus winter mean) of SLP (hPa, shading) and 850 hPa wind (m s$^{-1}$, vector) during (a) DJF 2013–2017 and (b) DJF 1999–2018 over YRD. Dotted regions mark statistically significant differences at the 95 % level. Grey shading represents the YRD region.
Figure S3: Correlation coefficients of UKESM1-simulated daily PM$_{2.5}$ concentrations in BTH with (a) Z500, (b) SLP and (c) V850 during DJF 1999–2018 (dotted regions indicate significant correlations at the 95% level from a two-tailed Student’s t-test). Grey shading represents the BTH region. The region used for the definition of a circulation-based index for BTH is marked by a yellow rectangle in panel c. (d) As in Figure 7 of the main text, but for the circulation-based index for BTH.
Figure S4: Correlation coefficients of UKESM1-simulated daily PM$_{2.5}$ concentrations in PRD with (a) Z500, (b) SLP and (c) V850 during DJF 1999–2018 (dotted regions indicate significant correlations at the 95% level from a two-tailed Student’s $t$-test). Grey shading represents the PRD region. The region used for the definition of a circulation-based index for PRD is marked by a yellow rectangle in panel b. (d) As in Figure 7 of the main text, but for the circulation-based index for PRD.
Figure S5: (a) CMIP6 emission changes of organic carbon (OC) from fossil fuel combustion from historical 2014 to SSP3-7.0 2058. Winter mean (b) organic matter (OM) changes (µg/m³) and (c) PM$_{2.5}$ changes (µg/m³) during DJF 2014-2018 due to emission reductions over YRD. The red box represents the YRD region.
Figure S6: Frequency distributions of daily mean $I_{SLP\_YRD}$ during DJF 1999-2014 from nudged UKESM1 and from the UKESM1 historical run in the CMIP6 archive. The vertical lines and shading represent the mean values and the associated 95% confidence intervals, respectively.
Figure S7: Frequency distributions of daily mean circulation-based indices for (a) BTH and (b) PRD during winter for present day (1995-2014), mid-century (2039-2058) and the end of century (2079-2098).
Figure S8: Joint distributions of daily $I_{SLP,YRD}$ against PM$_{2.5}$ concentrations over YRD for different percentile thresholds (colour coded), including the corresponding linear fits with 95 % prediction intervals, during DJF 1999–2018.
Figure S9: Normal frequency distributions of daily mean climate-driven PM$_{2.5}$ concentrations (µg/m$^3$) over YRD during winter over present day (1995-2014), mid-century (2039-2058) and the end of century (2079-2098). The vertical lines and shading represent the mean values and the associated 95% confidence intervals, respectively.
Figure S10: Time series of winter mean $I_{SLP\_YRD}$ from historical (1995–2014) and (a) future (2015–2098, SSP1-2.6) simulations, (c) future (2015–2098, SSP2-4.5) simulations of UKESM1 in the CMIP6 archive. Blue, orange and red areas represent present day (1995–2014), mid-century (2039–2058) and the end of century (2079–2098), respectively. (b) (d) Frequency distributions of daily mean $I_{SLP\_YRD}$ during winter over each period. The horizontal lines and shading represent the mean values and the associated 95% confidence intervals, respectively.
Table S1: Winter mean anthropogenic emissions of sulphur dioxide (SO$_2$), organic carbon (OC) and black carbon (BC) in 2014 (CMIP6 historical) and 2058 (CMIP6, scenario SSP3-7.0) over YRD, north China and south China. The three regions are displayed on Figure 8.

<table>
<thead>
<tr>
<th>Emissions (Unit: $10^{-10}$ kg/m$^2$/s)</th>
<th>YRD</th>
<th>north China</th>
<th>south China</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2014</td>
<td>2058</td>
<td>2014</td>
</tr>
<tr>
<td>SO$_2$</td>
<td>6.17</td>
<td>3.18</td>
<td>5.74</td>
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<tr>
<td>OC</td>
<td>0.73</td>
<td>0.77</td>
<td>0.86</td>
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<tr>
<td>BC</td>
<td>0.39</td>
<td>0.35</td>
<td>0.44</td>
</tr>
<tr>
<td>Total</td>
<td>7.29</td>
<td>4.30</td>
<td>7.04</td>
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</tbody>
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